Energy Star Homes: Actual Energy Usage

Presented to: Northeast HERS Alliance
based on talk at ACI 2008 (RES 8)

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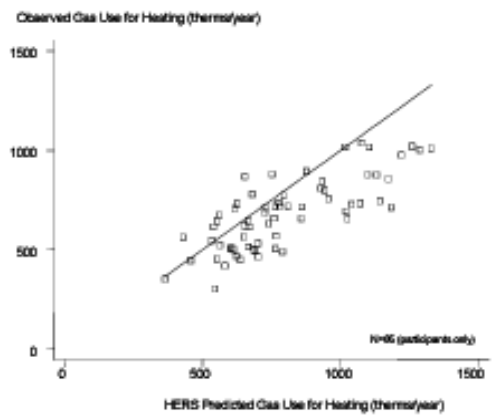
Wisconsin Energy Star Homes Study

"Energy Savings from the Wisconsin Energy Star Homes Program", S. Pigg, ECW 211-1, Oct 2002

- "Best" evaluation of Energy Star Homes program
  - 1999/2000 new ES homes and non ES homes
- Key Findings
  - ES Home gas use averaged 928 th/yr (n=97 homes)
  - Non ES use= 1024 (157 homes)
  - Both groups similar to state average use due to larger size
  - Gas Savings = 96 therms, 9%
  - Savings attributed to tighter buildings
  - Electric usage ~ 9,500 kWh/yr , net ~ 4% savings, large uncertainty
- Projected Usage
  - HERS projections 10% high, attributed to duct leakage assumptions
  - Typical Difference=18%
  - 56% of homes within ± 20%, 25% of homes within ± 10%
  - But living area was nearly as good a predictor as the rating:
    - sq.ft. accounted for 50% of variation, REM projected accounted for 52%

Wisconsin HERS Study

Figure 3, Observed versus predicted heating energy use.



New York Energy Star Homes

- Part of NYSERDA-sponsored project to assess design options to reach HERS 90 (score)
  - VEIC prime contractor
- Reviewed ratings data on 1,974 ES homes
  - Upstate NY, built 2004 to late 2006
  - Most Homes scored 87-89, 96 scored >90
  - Compared high scoring homes to <90 homes
- Assessed actual gas and electric usage to examine how real world performance varies

High Scoring Home Characteristics

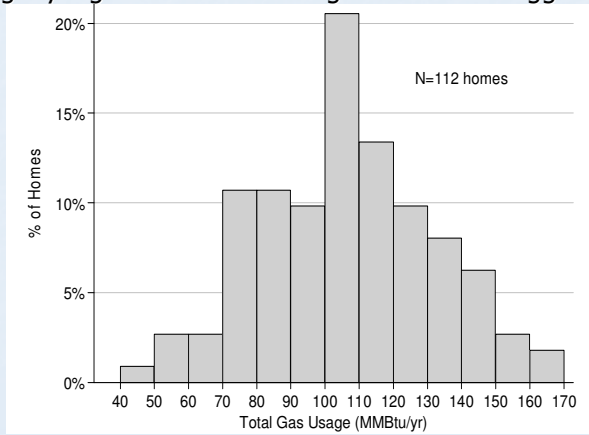
- Nearly all gas or propane heat/HW, ducts in basements
- Higher Score = Larger, more luxurious
  - 4012 sq.ft. (vs. 3687)
  - 9.5' ceilings (vs. 8.5), 3.2 BRs (vs. 3.5), 30% 1 story (vs. 19%)
- Central AC: 51% (vs. 35%)
- Walls – biggest difference in projected loads
  - 2x6 73% (vs. 39%), Foam 16% (vs. 2%), R-17 (vs. 13)
- Ducts – 2nd biggest difference
  - Default duct loss 18% (vs. 59%), hydronic 18% (vs. 1%),
  - Duct blaster tested 64% (vs. 40%), CFM25 = 89 (vs. 151)
- Air Leakage: similar
  - 1762 CFM50 (vs. 1835), 3.1 vs. 3.6 ACH50
- Hot Water
  - Tankless 32% (vs. 2%), Integrated 16% (vs. 1%)
- Foundations
  - Conditioned basements 71% (vs. 89%), R-wall 20.4 (vs. 16.5)
  - Conditioned Crawl or Slab 18% (vs. 1%)

NY Energy Usage Analysis

- Mailing sent to 887 ES Homes completed in 2005 to request fuel bill release forms
  - 240 responses (27% response rate)
- Cleaned up and analyzed gas and electric usage using weather normalization method
  - Gas results for 112 homes, electric for 129 homes
  - Virtually all homes had gas heat and hot water and conventional water heaters
  - Gas Analysis Sample averages
    - HERS 87.9, none >90
    - Floor area= 3,609, 81% 2 story, 3.5 bedrooms

NY Gas Usage results

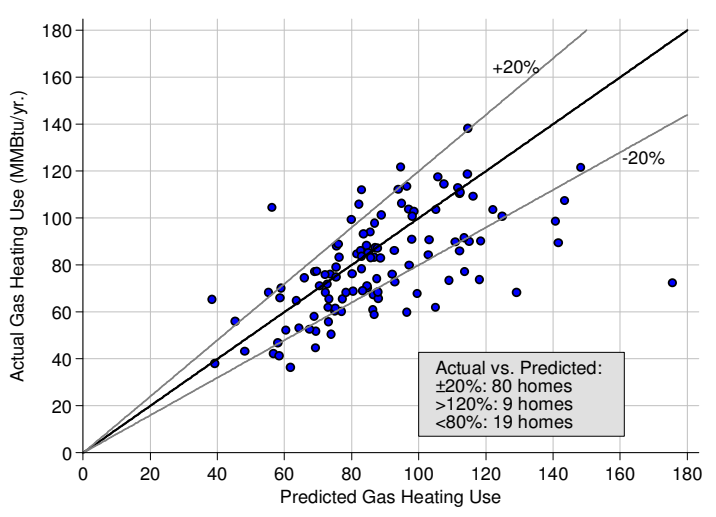
- Average actual usage = 1069 therms/yr (~$1,800/yr)
  - 804 therms heating, 265 therms baseload
  - slightly higher than the average customer – bigger house effect



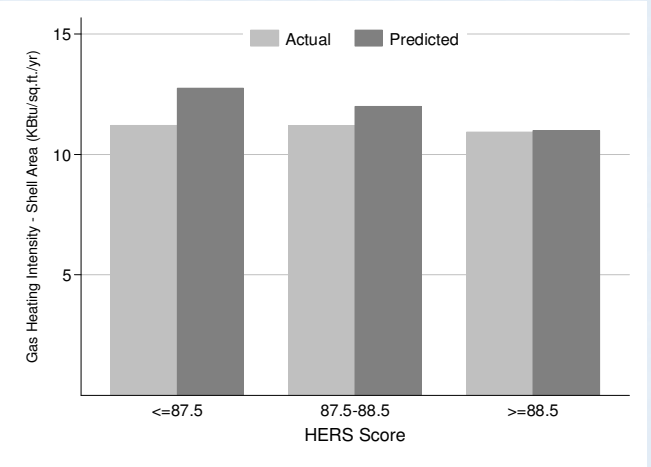
Actual vs. Projected Gas Heating Usage

- REM-projected usage averaged 1,190 total
  - 881 heat vs. 804 actual
  - 309 base vs. 265 actual
  - REM over-predicted by ~10% on average
  - Typical (median) discrepancy was 17%
  - Correlation pretty good, but house size drives much of the relationship

Actual vs. Projected Gas Heating Usage



Actual Gas Usage vs. HERS Score



Performance Discrepancies

Actual vs. Predicted Usage (KBtu/sq.ft. shell)

Characteristic	# Homes	Actual	Predicted	*Ratio*
HERS Score				
86.0-86.9	13	11.47	13.37	86%
87.0-87.9	50	10.99	12.30	89%
88.0-88.9	37	11.02	11.63	95%
>=89.0	12	11.74	10.61	111%
Duct Testing				
Duct Leakage Measured	43	11.51	11.82	97%
Default Ducts	69	10.90	12.15	90%
Wall Framing 2x6				
2x6 walls	45	10.98	11.32	97%
Not 2x6 walls	67	11.24	12.49	90%
Basement				
Conditioned Basement	93	10.73	11.88	90%
Unconditioned Basement	17	12.90	12.92	100%

Modeling Discrepancies

- HERS Scores apparently not related to energy usage within 86-89 range
- REM estimates of heating loads from walls, infiltration, windows, and ceilings are correlated with actual usage
  - better predictor of usage than REM projected total load
  - Slightly better than using just areas and CFM50
    - explained variance (R-squared) increased from 0.48 to 0.49
- REM estimates of duct losses and foundation losses had no discernible relation to measured gas usage
- Duct testing doesn't reduce heating usage (duh?)
- 2x6 walls might not save as much as projected
- Homes with unconditioned basements seems to use more than expected vs. conditioned basements

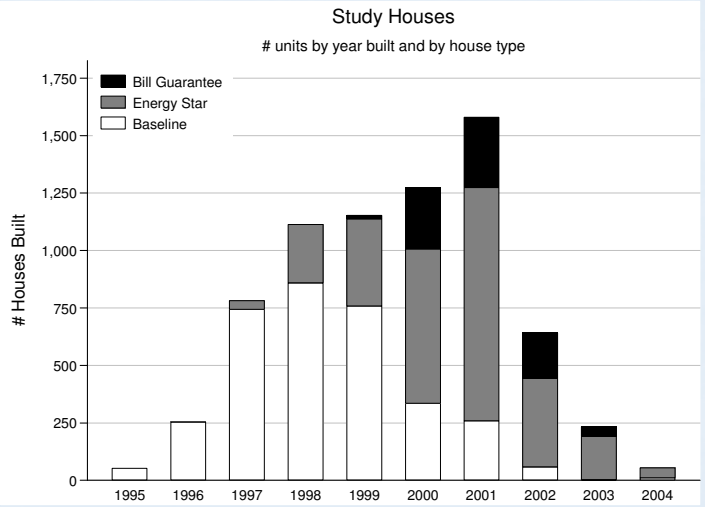
NY Electric Usage Results

- Usage averaged 11,040 kWh/yr (~$1,650/yr)
  - 9,333 kWh baseload
  - 829 kWh winter/heating load
  - 878 summer/cooling loads
    - Homes with central AC used 990 kWh summer/cooling vs. 896 kWh projected cooling
    - But homes without Central AC used 814 kWh
- Electric usage is higher than average residential customer (~8,000 kWh/yr)
  - house size and luxury

Energy Use of New Homes In Phoenix

- Sponsored by EPA
  - Advanced Energy prime contractor
- Examined 7,165 homes built 1995 - 2004
  - 3 primary efficiency categories:
    - 3,339 baseline homes
    - 2,998 Energy Star homes
    - 828 Guaranteed Bill homes
  - 6 major production builders:
  - Not a designed experiment, not a random sample

Production by category & year built



Baseline Homes: a moving target?

- Energy Star compliance primarily involved SEER 12 and/or low-e windows
  - Phoenix construction (slab, stucco) is already tight
- But…many new homes already met these standards
  - 2 builders: all SEER 12 A/C and low-e windows
  - All but 1 builder used all SEER 12 A/C
- As 2 efficient builders switched production to Energy Star, Baseline homes became less efficient
- Overall, slightly more than half of the Baseline homes were potentially already Energy Star

House Characteristics

Characteristic	Baseline Homes All	High Eff	Other	Energy Star	Guarantee Bill
# Homes	3,339	1,805	1,534	2,998	828
Year Built	1998	1998	1999	2000	2001
Living Area (sq.ft)	1728	1724	1732	1870	2164
# Stories	1.19	1.21	1.16	1.24	1.15
All Electric	61%	54%	69%	40%	0%
Swimming Pool	18%	19%	16%	17%	19%
A/C SEER	11.6	**12.0**	10.3	11.9	11.6
A/C tons	4.0	4.0	3.8	4.4	4.8
A/C size: sq.ft/ton	425	424	428	424	468
Windows: low-e	56%	**70%**	0%	58%	100%

- Baseline homes are smallest, specs similar to Energy Star
- Guarantee Bill homes are largest, all gas heat, all low-e windows, ~10% smaller A/C tons/ft²

Electric Usage Data

- 7,161 homes, 1998-2004, 400,000 meter reads
  - Data cleaning - remove suspected vacant periods
  - Weather normalization: each house, each year
    - Heating/Cooling degree day adjustment procedure
      - HDD65 , CDD75 (derived from analysis on cooling-only houses)
      - 8% of houses classified as unreliable, mostly too few readings
    - Limitations
      - Seasonal end uses affect results: swimming pools, water heaters, fans, refrigerators and lighting are seasonal
      - Fortunately, the focus of the analysis was 2004, which had typical weather (99% of typical CDD), reducing bias

Electric Usage Results Summary

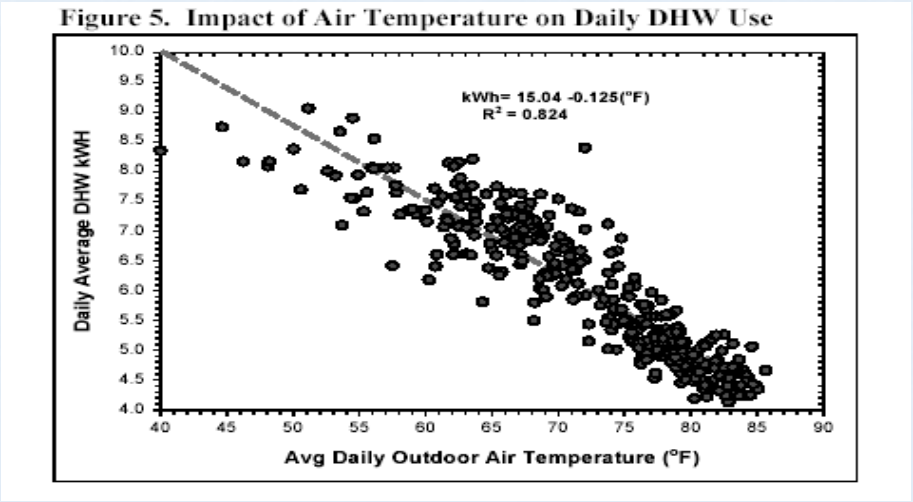
	Baseline Homes All	BaseES	BaseReg	Energy Star	Guarantee Bill
All Electric: % homes	62%	53%	70%	40%	0%
Electric Heat / Hot Water:					
Living Area	1686	1578	1775	1526	N/A
Total Use	17,501	16,280	18,508	15,311	N/A
Baseload	11,581	10,745	12,270	10,070	N/A
Summer/Cooling	4,804	4,397	5,139	4,298	N/A
Winter/Heating	1,117	1,138	1,099	942	N/A
Total kWh/ft²	10.55	10.52	10.58	10.12	N/A
Summer/Cooling /ft²	2.87	2.81	2.93	2.83	N/A
Gas Heat / Hot Water:					
Living Area	1825	1916	1670	2117	2206
Total Use	15,579	15,691	15,386	17,738	16,725
Baseload	8,978	9,001	8,939	10,357	10,434
Summer/Cooling	6,322	6,341	6,288	7,214	6,078
Winter/Heating	279	349	159	167	212
Total kWh/ft²	8.7	8.29	9.40	8.53	7.73
Summer/Cooling /ft²	3.57	3.34	3.97	3.5	2.85

Electric Results

- All categories used about 17,000 kWh/yr.
  - But baseline homes are smaller
- Baseload usage is about two thirds of total
- Cooling loads ~30% of usage
- All Electric: higher baseload (as expected), but apparently smaller summer/cooling loads than gas
  - Seasonal water heater usage makes summer loads look smaller
- Gas: Energy Star comparable to average Baseline, about 11% better than "regular" Baseline, Guaranteed Bill homes about 20% better than Energy Star

Hot Water kWh vs. Outdoor Temperature

Sub-meter date from Florida



Apples to Apples?

- All electric homes vs. gas homes
  - Analyze separately, too many differences to directly compare
  - No Guarantee Bill homes were all electric
- Swimming Pools
  - About 19% of homes have pools
  - Houses with pools used ~ 7,000 kWh more, but were also bigger
  - Pool electric usage adds a big wild card into any analysis
- "Best" analysis group is gas heated homes without pools
  - Still 877 Baseline, 1,195 Energy Star, and 560 Guarantee Bill homes

Electric Usage Results:

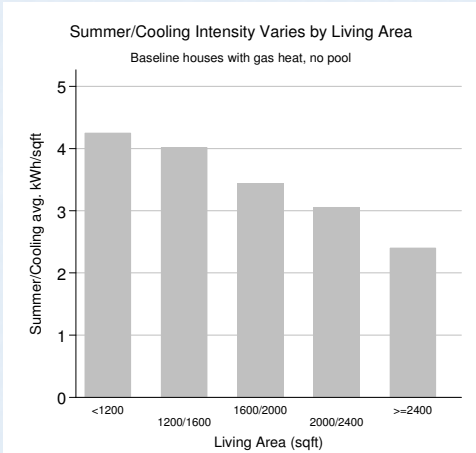
gas heated homes without pools

	Baseline Homes				
	All	BaseES	BaseReg	Energy Star	Guarantee Bill
Gas No Pool: # homes	877	537	340	1195	560
Living Area	1735	1878	1509	1967	2112
Total Use	14,107	14,228	13,915	15,831	14,904
Baseload	7,797	7,827	7,750	8,936	8,996
Summer/Cooling	6,064	6,054	6,080	6,736	5,694
Total kWh/ft²	8.36	7.71	9.39	8.22	7.27
Summer/Cooling /ft²	**3.60**	**3.26**	**4.16**	**3.50**	**2.80**
Baseload /ft²	4.62	4.27	5.18	4.64	4.37

- Cooling Intensity Differences
  - Energy Star homes slightly lower kWh/ft² than average Baseline
  - Energy Star equivalent Baseline homes (BaseES) mused less than BaseReg
  - Guarantee Bill homes 20% better than Energy Star, 23% better than average Baseline, 33% better than BaseReg. Also the largest homes.

The Problem with kWh/ft²

- Common way to compare homes of different sizes, but does it solve the problem or create a new one?
- Graph shows kWh/ft² is lower for larger homes
  - Building shell and window areas don't double if floor area doubles
  - Also true for baseload usage



Apples to Apples…continued

- Even when looking at gas heated homes without pools, differences in living area are not properly accounted for by kWh/ft² comparisons
- Average living area differs substantially between Baseline, Energy Star and Guarantee Bill homes
- Need to compare comparable sized homes to each other…or,
- Use regression model to model living area effect better and create a "level playing field"

Summer/Cooling Intensity Comparisons: controlling for house size

	Baseline Homes				
	All	BaseES	BaseReg	Energy Star	Guarantee Bill
Homes < 1600 ft²					
# Homes	407	125	282	326	141
Summer/Cooling /ft²	4.06	3.27	4.41	3.63	3.53
Homes 1601-2400 ft²					
# Homes	435	398	37	660	282
Summer/Cooling /ft²	3.28	3.29		3.59	2.68
Homes >2401 ft²					
# Homes	34	14	20	208	136
Summer/Cooling /ft²				3.02	2.30

- Small Homes: EStar 11% better, GBill 13% better than Baseline, but BaseES actually looks best
- Medium Homes: 90% of Baseline meet ES, EStar use more than Baseline while GBill use 18% less
- Larger Homes: too few Baseline, GBill uses 24% less than EStar.

Regression Modeling of Electric Usage

- Regression models attempt to estimate the separate effects of multiple factors simultaneously
  - Results should be considered only indicative, not definitive. Many unknowns remain like building design/characteristics, etc…
- Some regression findings
  - 1800 ft² home with gas heat and no pool: summer/cooling loads are estimated at 6,413 kWh for average Baseline, 6,493 kWh for EStar, and 5,409 kWh for GBill (16% savings)
  - Compared to BaseReg, EStar use 10% less for summer/cooling and GBill use 25% less summer/cooling
  - Swimming pools are estimated to use by about 4500 kWh/yr. with about 750 kWh as added summer/cooling load. This large end use may be worth addressing (pump sizing/scheduling?)

Occupant Effects

- Analyzed occupant effects by comparing the usage of homes with moves vs. no moves
  - Total and summer/cooling use in 2000 vs. 2004 for 1289 movers and 1384 stayers
    - Summer/Cooling usage averaged 5% lower in 2004 for both movers and stayers
    - The typical (median) change in usage between 2000 to 2004 was 14% for stayers and 21% for movers, implying that occupancy changes are typically responsible for less than a 10% change in use
    - More movers experienced large changes in usage compared to stayers – 1 in 4 movers showed a usage change of 40% or more, but only 1 in 10 stayers showed that large a change.

Houston Energy Star Homes

- ~60,000 ES homes built in past 6 years
- Getting electric and gas usage data and (hopefully!) RemRate files for most homes
- Developing comparison group from county property assessor databases (4 counties)
- Working on analysis now (and waiting for RemRate data)